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(73) Proprietor: **INTERNATIONAL FUEL CELLS CORPORATION**
185 Governor's Highway
South Windsor, Connecticut 06074(US)

(72) Inventor: **Scheffler, Glenn W.**
7 Willie Circle
Tolland Connecticut 06084(US)
Inventor: **Vartanian, George**
4 Hayes Avenue
Ellington Connecticut 06029(US)

(74) Representative: **Bleyer, Jean et al**
OFFICE DENNEMEYER S.à.r.l. P.O. Box 1502
L-1015 Luxembourg (LU)

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Rank Xerox (UK) Business Services
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Description

This invention relates to a system and method for controlling the amount of oxygen flowing to the cathodes in a fuel cell stack when the stack is operating at partial power levels.

US-A-4,202,933 granted May 13, 1980 to C. A. Reiser et al discloses a system and method for reducing fuel cell output voltage to permit low power operation of a fuel cell stack. The patented system recycles the cathode exhaust stream back to the cathode inlet and also reduces the amount of fresh oxygen fed into the cathode by reducing the airflow to the cathode inlet. The adjustments are made by comparing the desired power output with the actual power output, with the incoming airflow being reduced until actual power is as close to desired power as possible. A sensor monitors the amount of fresh air flowing into the system. Thus, the patented system depends on current measurement and incoming airflow rate measurement for its operation. Use of the patented system can result in individual cell starvation because no measurement of the amounts of oxygen consumed in the stack are made. Additionally, the flow rate sensor measuring the airflow will be operating at the low end of its operable range due to airflow throttling, whereby the accuracy of the air flow rate sensor will be at its poorest. Cells which are starved for oxygen can break down to a degree which will adversely effect the performance of the entire stack.

According to the invention there if now proposed a cathode air flow control system for use in a fuel cell power plant to minimize oxygen starvation of fuel cells in the power plant, said system comprising a fresh air inlet for admitting air into the cathodes of the fuel cells in the power plant, means 32 in said fresh air inlet for varying the amount of fresh air admitted to said cathodes, a cathode exhaust outlet 20 for exhausting oxygen-depleted gas from the cathodes, a cathode exhaust recirculating loop 24 for recirculating oxygen-depleted gas from said exhaust outlet 20 to said fresh air inlet, characterized by;

a) a sensor 22 in said cathode exhaust outlet 20 for measuring the oxygen content of the oxygen-depleted gas therein;

b) a sensor 33 in said air inlet to measure the combined flow of incoming air and recirculated oxygen-depleted gas in said air inlet so as to effectively measure the total amount of flow conveying oxygen to the cathodes;

c) said recirculation loop 24 being connected to said fresh air inlet at a location 26 between said means 32 for varying the amount of fresh air admitted and the fuel cell but upstream of said sensor 33;

d) current output monitor 42 for continuously measuring the electrical current output of the power plant; and

e) control 34 operably connected to said means for varying the amount of fresh air admitted to the cathodes, to said sensor 22, said sensor 33 and to said current output monitor 43, said control 34 being operable to calculate oxygen utilization in said cathodes, and cause said means 32 to increase or decrease the amount of air in said air inlet in response to changes in the measured oxygen utilization and to modulate the amount of recirculating air to limit the maximum voltage produced at low current output.

This system achieves the advantage that it lessen or eliminate the incidence of cell starvation at partial loads because the amount of oxygen consumed in the stack is a factor which is used to control the feeding of oxygen to the stack. In the system of this invention, the total oxygen flow rate into the cathodes is measured by a sensor which is exposed to the combined cathode inlet stream, i.e., the mixture of gases formed after the recycled cathode exhaust is mixed with the incoming fresh air. This ensures that the sensor will not be subjected to the low air flow rates that it encounters in US-A-4,202,933 patent system. The accuracy of the sensor is thus increased. The more accurate measurement in air inlet flow, combined with the measurement of oxygen in the cathode exhaust, provides an accurate picture of the oxygen consumption in the stack, so that the incidence of individual cell starvation is minimized.

Preferably the control 34 is a microprocessor which is preprogrammed to continuously calculate the optimum oxygen utilization for existing current output and wherein said microprocessor 34 is further operable to adjust said means 32 for varying to compensate for differences between the optimum oxygen utilization and the measured oxygen utilization to minimize differences therebetween.

In one preferred arrangement the control 34 is operable to calculate oxygen utilization based on the electric current, the oxygen content in said oxygen depleted gases and the measured combined flow conveying oxygen to the cathodes.

The invention does also propose a method for minimizing the risk of oxygen starvation in individual cells of a fuel cell power plant during periods of operation thereof at partial load levels, said method comprising the steps of providing a stream of fresh air to a cathode inlet 18, providing a stream of oxygen depleted exhaust air in a cathode exhaust portion 20, circulating some of said exhaust air for admixture with said stream of fresh air to form a gas mixture for use at the cathodes during periods of partial load levels,

characterized by

a) continuously measuring the oxygen content of said exhaust air by means of sensor 22;

b) continuously measuring the current output of said power section by means of a current output monitor 43;

c) continuously measuring the flow rate of said gas mixture by means of a sensor 33;

d) continuously calculating the oxygen utilization in the power section as a function of the measured current output, the measured flow rate of said gas mixture, and the measured oxygen content in the exhaust air;

e) comparing by means of a control 34 the calculated oxygen utilization with a known-optimal oxygen utilization corresponding to the measured electrical current output values;

f) varying by means 32 the amount of air being admitted through said fresh air inlet 18 so as to reduce noted differences between said calculated oxygen utilization and said optimal oxygen utilization;

g) modulating the amount of recirculating air to limit the maximum voltage produced at low current output and introducing the recirculating air at a location 26 between said means for varying the amount of fresh air admitted and the fuel cell but upstream of said sensor 33.

Preferably the oxygen consumed is calculated as a function of the measured current output; and the oxygen utilization is calculated as a function of the oxygen consumed, the oxygen content of the exhaust air and the flow rate of the gas mixture.

In one preferred arrangement the step of measuring the flow rate of the gas mixture comprises measuring said flow rate at the inlet 18 to said cathode;

the step of calculating oxygen consumed in mols/hour comprises multiplying the measured current in amps by 2.06×10^{-5}; and

the oxygen utilization (UO_2) is calculated according to

$$UO_2 = \frac{O_2CONS}{O_2CONS + XO_2(Win + O_2CONS)}$$

where O_2CONS is oxygen consumed., XO_2 is the fractional oxygen content of the exhaust air, Win is the measured flow entering the cathode expressed in consistent units.

Preferably the amount of recirculated air is increased as the current output decreases.

The advantages of the invention will become more readily apparent from the following detailed description of a preferred embodiment thereof when taken in conjunction with the accompanying drawing which is a schematic representation of a fuel cell stack which employs the cathode flow control of this invention.

Referring to the drawing, there is shown schematically a fuel cell power plant which employs the cathode feed system of this invention. The power plant includes a fuel cell stack 2 having an anode side 4, a cathode side 6, and a water cooling system 8. Hydrogen rich fuel gas enters the anode side 4 through anode inlet 10 and the hydrogen depleted exhaust leaves the anode side 4 through anode outlet 12. The water coolant enters the cooling system 8 through coolant inlet 14, and leaves the cooling system 8 as a two phase water/steam mixture through coolant outlet 16. The remainder of the fuel and coolant subsystems in the plant do not form a part of this invention, and thus are not disclosed herein. They may take conventional forms and include conventional components.

The oxygen-bearing gas, such as air, enters the cathode side 6 via cathode inlet 18 and exhaust from the cathode side 6 leaves through cathode exhaust line 20. A sensor 22 for monitoring the oxygen content of the cathode exhaust is disposed in the cathode exhaust line 20. A cathode exhaust recirculating loop 24 extends from the cathode exhaust line 20 to the cathode inlet 18, joining the cathode inlet line 18 at juncture 26. The cathode exhaust recirculating loop 24 is activated and modulated by a variable speed blower 28. The fresh air supply fed into the cathode inlet 18 is moved by a blower 30, and the amount of fresh air entering the cathode inlet line 18 is controlled by a modulating valve 32. An air flowmeter 33 is disposed in the cathode inlet line 18 between the cathode 6 and the cathode exhaust recycle juncture 26. The flowmeter 33 thus, in effect, measures the total oxygen flowing into the cathode 6, i.e., the amount contributed by the recycled cathode exhaust, plus the amount contributed by the air.

The system of the invention is operated by the power plant microprocessor control 34. The power plant control 34 receives a signal 36 from the cathode exhaust oxygen sensor, plus a signal 38 from the air inlet flow monitor 33, and also a signal 40 from a current output monitor 42 which measures the current load on

the stack 2. With this data, the control 34 solves several previously inputted algorithms to determine the appropriate setting of the air inlet valve 32. Knowing the current I from the monitor 42, the control 34 calculates the oxygen molar consumption rates, O_2CONS, by solving the following equation based on Faraday's law:

$$O_2CONS = 2.06 \times 10^{-5} . I$$

The control 34 then determines the actual oxygen utilization UO_2 for the existing current, by solving this equation:

$$UO_2 = \frac{O_2\ CONS}{O_2\ CONS + XO_2(Win + O_2CONS)}$$

Where XO_2 is the cathode exhaust oxygen concentration, which is derived from the sensor 22, and Win is the total inlet gas flow derived from the sensor 33. The control will have inputted therein valve settings for the valve 32 which correlate to desired UO_2 values at known currents, and will adjust the setting of the valve 32 to compensate for any differences between the desired UO_2 (which safeguards against individual cell starvation) and the measured UO_2. In this manner, the system constantly provides protection against individual fuel cell oxygen starvation when the plant is running at partial load levels.

It will be readily appreciated that the system and method of this invention will provide for more accurate instrument readings since the instrument for measuring incoming oxygen will not be required to operate at its lowest sensitivity levels. Additionally, since oxygen utilization in the stack is the key to ensuring that individual cells in the stack do not suffer from oxygen starvation, and the system is operable to measure oxygen utilization and adjust airflow to achieve optimum oxygen utilization for existing current output, the stack 6 is better protected against internal damage by the system of this invention.

Claims

1. A cathode air flow control system for use in a fuel cell power plant to minimize oxygen starvation of fuel cells in the power plant, said system comprising a fresh air inlet for admitting air into the cathodes of the fuel cells in the power plant, means 32 in said fresh air inlet for varying the amount of fresh air admitted to said cathodes, a cathode exhaust outlet 20 for exhausting oxygen-depleted gas from the cathodes, a cathode exhaust recirculating loop 24 for recirculating oxygen-depleted gas from said exhaust outlet 20 to said fresh air inlet, characterized by;
   a) a sensor 22 in said cathode exhaust outlet 20 for measuring the oxygen content of the oxygen-depleted gas therein;
   b) a sensor 33 in said air inlet to measure the combined flow of incoming air and recirculated oxygen-depleted gas in said air inlet so as to effectively measure the total amount of flow conveying oxygen to the cathodes;
   c) said recirculation loop 24 being connected to said fresh air inlet at a location 26 between said means 32 for varying the amount of fresh air admitted and the fuel cell but upstream of said sensor 33;
   d) current output monitor 42 for continuously measuring the electrical current output of the power plant; and
   e) control 34 operably connected to said means for varying the amount of fresh air admitted to the cathodes, to said sensor 22, said sensor 33 and to said current output monitor 43, said control 34 being operable to calculate oxygen utilization in said cathodes, and cause said means 32 to increase or decrease the amount of air in said air inlet in response to changes in the measured oxygen utilization and to modulate the amount of recirculating air to limit the maximum voltage produced at low current output.

2. The system according to claim 1, characterized in that said control 34 is a microprocessor which is preprogrammed to continuously calculate the optimum oxygen utilization for existing current output and wherein said microprocessor 34 is further operable to adjust said means 32 for varying to compensate for differences between the optimum oxygen utilization and the measured oxygen utilization to minimize differences therebetween.

3. The system according to any of claims 1 or 2, characterized in that said control 34 is operable to calculate oxygen utilization based on the electric current, the oxygen content in said oxygen depleted gases and the measured combined flow conveying oxygen to the cathodes.

4. A method for minimizing the risk of oxygen starvation in individual cells of a fuel cell power plant during periods of operation thereof at partial load levels, said method comprising the steps of providing a stream of fresh air to a cathode inlet 18, providing a stream of oxygen depleted exhaust air in a cathode exhaust portion 20, circulating some of said exhaust air for admixture with said stream of fresh air to form a gas mixture for use at the cathodes during periods of partial load levels, characterized by

a) continuously measuring the oxygen content of said exhaust air by means of sensor 22;

b) continuously measuring the current output of said power section by means of a current output monitor 43;

c) continuously measuring the flow rate of said gas mixture by means of a sensor 33;

d) continuously calculating the oxygen utilization in the power section as a function of the measured current output, the measured flow rate of said gas mixture, and the measured oxygen content in the exhaust air;

e) comparing by means of a control 34 the calculated oxygen utilization with a known-optimal oxygen utilization corresponding to the measured electrical current output values;

f) varying by means 32 the amount of air being admitted through said fresh air inlet 18 so as to reduce noted differences between said calculated oxygen utilization and said optimal oxygen utilization;

g) modulating the amount of recirculating air to limit the maximum voltage produced at low current output and introducing the recirculating air at a location 26 between said means for varying the amount of fresh air admitted and the fuel cell but upstream of said sensor 33.

5. The method according to claim 4, characterized by calculating the oxygen consumed as a function of the measured current output; and calculating the oxygen utilization as a function of the oxygen consumed, the oxygen content of the exhaust air and the flow rate of the gas mixture.

6. Method according to claim 5, characterized in that the step of measuring the flow rate of the gas mixture comprises measuring said flow rate at the inlet 18 to said cathode;

the step of calculating oxygen consumed in mols/hour comprises multiplying the measured current in amps by 2.06×10^{-5}; and

the oxygen utilization (UO_2) is calculated according to

$$UO2 = \frac{O2CONS}{O2CONS + XO2(Win + O2CONS)}$$

where O_2CONS is oxygen consumed., XO_2 is the fractional oxygen content of the exhaust air, Win is the measured flow entering the cathode expressed in consistent units.

7. Method according to claim 4, characterized by increasing the amount of recirculated air as the current output decreases.

Patentansprüche

1. Katodenluftströmungsregelsystem zur Verwendung in einer Brennstoffzellenkraftanlage zum Minimieren von Sauerstoffmangel von Brennstoffzellen in der Kraftanlage, wobei das System einen Frischlufteinlaß zum Einlassen von Luft in die Katoden der Brennstoffzellen in der Kraftanlage aufweist, eine Einrichtung 32 in dem Frischlufteinlaß zum Verändern der Menge an Frischluft, die zu den Katoden gelassen wird, einen Katodenabgasauslaß 20 zum Abgeben von sauerstoffabgereichertem Gas aus den Katoden, eine Katodenabgasrezirkulationsschleife 24 zum Rezirkulieren von sauerstoffabgereichertem Gas von dem Abgasauslaß 20 zu dem Frischlufteinlaß, gekennzeichnet durch:

a) einen Sensor 22 in dem Katodenabgasauslaß 20 zum Messen des Sauerstoffgehalts des sauerstoffabgereicherten Gases darin;

b) einen Sensor 33 in dem Lufteinlaß zum Messen der kombinierten Strömung von ankommender Luft und rezirkuliertem sauerstoffabgereicherten Gas in dem Lufteinlaß, um so die Gesamtströmungsmenge, die Sauerstoff zu den Katoden fördert, effektiv zu messen;
c) wobei die Rezirkulationsschleife 24 mit dem Frischlufteinlaß an einer Stelle 26 zwischen der Einrichtung 32 zum Verändern der Menge an eingelassener Frischluft und der Brennstoffzelle, aber stromaufwärts des Sensors 33, verbunden ist;
d) eine Ausgangsstromüberwachungseinrichtung 42 zum ständigen Messen des elektrischen Ausgangsstroms der Kraftanlage; und
e) einen Regler 34, der mit der Einrichtung zum Verändern der zu den Katoden gelassenen Frischluftmenge, mit dem Sensor 22, mit dem Sensor 33 und mit der Ausgangsstromüberwachungseinrichtung 43 betriebsmäßig verbunden ist, wobei der Regler 34 in der Lage ist, die Sauerstoffausnutzung in den Katoden zu berechnen und die Einrichtung 32 zu veranlassen, die Menge an Luft in dem Lufteinlaß aufgrund von Änderungen in der gemessenen Sauerstoffausnutzung zu erhöhen oder zu verringern und die Menge an Rezirkulationsluft zu beeinflussen, um die maximale Spannung zu begrenzen, die bei niedrigem Ausgangsstrom erzeugt wird.

2. System nach Anspruch 1, dadurch gekennzeichnet, daß der Regler 34 ein Mikroprozessor ist, der vorprogrammiert ist, um die optimale Sauerstoffausnutzung bei vorhandenem Ausgangsstrom ständig zu berechnen, wobei der Mikroprozessor 34 weiter in der Lage ist, die Einrichtung 32 einzustellen, um sich verändernde Differenzen zwischen der optimalen Sauerstoffausnutzung und der gemessenen Sauerstoffausnutzung zu kompensieren und Differenzen zwischen denselben zu minimieren.

3. System nach Anspruch 1 oder 2, dadurch gekennzeichnet, daß der Regler 34 in der Lage ist, die Sauerstoffausnutzung auf der Basis des elektrischen Stroms, des Sauerstoffgehalts in den sauerstoffabgereicherten Gasen und der gemessenen kombinierten Strömung, die Sauerstoff zu den Katoden fördert, zu berechnen.

4. Verfahren zum Minimieren der Gefahr eines Sauerstoffmangels in einzelnen Zellen einer Brennstoffzellenkraftanlage während Zeitspannen des Betriebes derselben mit Teillastwerten, wobei das Verfahren die Schritte beinhaltet, einen Strom von Frischluft einem Katodeneinlaß 18 zuzuführen, einen Strom von sauerstoffabgereichertem Abgas in einem Katodenabgasteil 20 zu liefern, einen Teil der Abluft zur Vermischung mit dem Strom von Frischluft umzuwälzen, um ein Gasgemisch zum Gebrauch an den Katoden während Zeitspannen mit Teillastwerten zu bilden, gekennzeichnet durch
a) ständiges Messen des Sauerstoffgehalts der Abluft mit Hilfe eines Sensors 22;
b) ständiges Messen des Ausgangsstroms des Leistungsteils mit Hilfe einer Ausgangsstromüberwachungseinrichtung 43;
c) ständiges Messen der Strömungsleistung des Gasgemisches mit Hilfe eines Sensors 33; d) ständiges Berechnen der Sauerstoffausnutzung in dem Leistungsteil als eine Funktion des gemessenen Ausgangsstroms, der gemessenen Strömungsleistung des Gasgemisches und des gemessenen Sauerstoffgehalts in der Abluft;
e) Vergleichen der berechneten Sauerstoffausnutzung mit einer bekannten optimalen Sauerstoffausnutzung mittels eines Reglers 34 entsprechend den gemessenen Werten des elektrischen Ausgangsstroms;
f) Verändern der Luftmenge, die über den Frischlufteinlaß 18 zugeführt wird, mittels einer Einrichtung 32, so daß festgestellte Differenzen zwischen der berechneten Sauerstoffausnutzung und der optimalen Sauerstoffausnutzung reduziert werden;
g) Beeinflussen der Menge an Rezirkulationsluft, um die maximale Spannung zu begrenzen, die bei niedrigem Ausgangsstrom erzeugt wird, und Einleiten der Rezirkulationsluft an einer Stelle 26 zwischen der Einrichtung zum Verändern der Menge an zugeführter Frischluft und der Brennstoffzelle, aber stromaufwärts des Sensors 33.

5. Verfahren nach Anspruch 4, gekennzeichnet durch Berechnen des verbrauchten Sauerstoffes als eine Funktion des gemessenen Ausgangsstroms; und Berechnen der Sauerstoffausnutzung als eine Funktion des verbrauchten Sauerstoffes, des Sauerstoffgehalts der Abluft und der Strömungsleistung des Gasgemisches.

6. Verfahren nach Anspruch 5, dadurch gekennzeichnet, daß der Schritt des Messens der Strömungsleistung des Gasgemisches beinhaltet, die Strömungsleistung an dem Einlaß 18 der Katode zu messen;

daß der Schritt des Berechnens des verbrauchten Sauerstoffes in Mol/Stunde beinhaltet, den gemessenen Strom in Ampère mit $2{,}06 \times 10^{-5}$ zu multiplizieren; und
daß die Sauerstoffausnutzung (UO_2) berechnet wird gemäß

$$UO_2 = \frac{O_2CONS}{O_2CONS + XO_2(Win + O_2CONS)}$$

wobei O_2CONS der verbrauchte Sauerstoff ist, XO_2 der fraktionelle Sauerstoffgehalt der Abluft ist, Win die gemessene Strömung ist, die in die Katode eintritt, ausgedrückt in geeigneten Einheiten.

7. Verfahren nach Anspruch 4, gekennzeichnet durch Erhöhen der Menge an rezirkulierter Luft, wenn der Ausgangsstrom sinkt.

Revendications

1. Système de contrôle de l'écoulement d'air vers les cathodes destiné à être utilisé dans une centrale de piles à combustible pour minimiser la privation en oxygène des piles à combustible de la centrale, ledit système comprenant une entrée d'air frais pour introduire l'air dans les cathodes des piles à combustible de la centrale, des moyens 32 dans ladite entrée d'air frais pour modifier la quantité d'air frais amenée auxdites cathodes, une sortie 20 d'échappement des cathodes pour évacuer des cathodes le gaz appauvri en oxygène, une boucle 24 de recyclage de l'échappement des cathodes pour renvoyer le gaz appauvri en oxygène de ladite sortie 20 d'échappement des cathodes vers ladite entrée d'air frais, ***caractérisé par*** :
   (a) un capteur 22 situé dans ladite sortie 20 d'échappement des cathodes destiné à mesurer la teneur en oxygène du gaz appauvri en oxygène qui s'y trouve;
   (b) un capteur 33 situé dans ladite entrée d'air destiné à mesurer le flux mixte composé d'air en entrée et de gaz appauvri en oxygène dans ladite entrée d'air afin de mesurer effectivement la valeur totale du flux transportant l'oxygène vers les cathodes;
   (c) ladite boucle 24 de recyclage étant raccordée à ladite entrée d'air frais en un emplacement 26 situé entre lesdits moyens 32 pour modifier la quantité d'air frais admise et la pile à combustible mais en amont dudit capteur 33;
   (d) un dispositif de contrôle 42 de la puissance du courant en sortie destiné à mesurer en continu la puissance du courant électrique en sortie de la centrale ; et
   (e) un organe de régulation 34 relié de manière opérationnelle auxdits moyens pour modifier la quantité d'air frais admise dans les cathodes, audit capteur 22, audit capteur 33 et audit dispositif de contrôle 42 de la puissance du courant en sortie, ledit organe de régulation 34 étant utilisable pour calculer l'utilisation en oxygène dans lesdites cathodes, et entraîner lesdits moyens 32 à augmenter ou à diminuer la quantité d'air dans ladite entrée d'air en réponse aux changements dans l'utilisation mesurée en oxygène et à moduler la quantité d'air recyclé pour limiter la tension maximum produite à faible puissance de sortie du courant.

2. Système selon la Revendication 1, ***caractérisé en ce que*** ledit organe de régulation 34 est un microprocesseur qui est préprogrammé pour calculer en continu l'utilisation optimum en oxygène pour la puissance effective de sortie du courant, et dans lequel ledit microprocesseur 34 est additionnellement utilisable pour régler lesdits moyens 32 pour qu'ils varient afin de compenser les différences entre l'utilisation optimum en oxygène et l'utilisation mesurée d'oxygène pour minimiser ces différences.

3. Système selon l'une quelconque des Revendications 1 ou 2, ***caractérisé en ce que*** l'organe de régulation 34 est utilisable pour calculer l'utilisation en oxygène basée sur le courant électrique, la teneur en oxygène dans lesdits gaz appauvris en oxygène et le flux mixte mesuré amenant l'oxygène vers les cathodes.

4. Procédé pour minimiser le risque de privation d'oxygène dans les piles individuelles d'une centrale génératrice à piles à combustibles pendant les périodes de fonctionnement de celle-ci à des niveaux

de charge partielle, ledit procédé comprenant les étapes consistant à four-nir un courant d'air frais à l'entrée 18 des cathodes, à fournir un courant d'air appauvri en oxygène dans une section 20 d'échappement des cathodes, à faire circuler une partie dudit air d'échappement en vue de son mélange avec ledit courant d'air frais afin de former un mélange gazeux utilisé dans les cathodes pendant les périodes de niveaux de charge partielle, ***caractérisé par:***

(a) la mesure en continu de la teneur en oxygène dudit air d'échappement au moyen d'un capteur 22;

(b) la mesure en continu de la puissance de sortie du courant de ladite section génératrice au moyen d'un dispositif de contrôle 42 de la puissance du courant en sortie;

(c) la mesure en continu du débit d'écoulement dudit mélange gazeux au moyen d'un capteur 33;

(d) le calcul en continu de l'utilisation en oxygène dans la section génératrice en fonction de la puissance mesurée du courant en sortie, du débit d'écoulement mesuré dudit mélange gazeux et de la teneur en oxygène mesurée dans l'air d'échappement;

(e) la comparaison au moyen d'un organe de régulation 34 de l'utilisation calculée de l'oxygène avec une utilisation optimale de l'oxygène connue correspondant aux valeurs mesurées de la puissance du courant en sortie;

(f) la modification par des moyens 32 de la quantité d'air admise par ladite entrée 18 d'air frais afin de réduire les différences notées entre ladite utilisation calculée de l'oxygène et ladite utilisation optimale de l'oxygène;

(g) la modulation de la quantité d'air recyclé pour limiter la tension maximum produite à puissance de courant en sortie faible et l'introduction de l'air recyclé en un emplacement 26 situé entre lesdits moyens pour modifier la quantité d'air admise et la pile à combustible mais en amont dudit capteur 33.

5. Procédé selon la Revendication 4, ***caractérisé en ce que*** l'oxygène consommé est calculé en fonction de la puissance mesurée du courant en sortie et l'utilisation en oxygène est calculée en fonction de l'oxygène consommé, de la teneur en oxygène de l'air d'échappement et du débit d'écoulement du mélange gazeux.

6. Procédé selon la Revendication 5, ***caractérisé en ce que*** l'étape de mesure du débit d'écoulement du mélange gazeux comprend la mesure dudit débit d'écoulement au niveau de l'entrée 18 de ladite cathode;

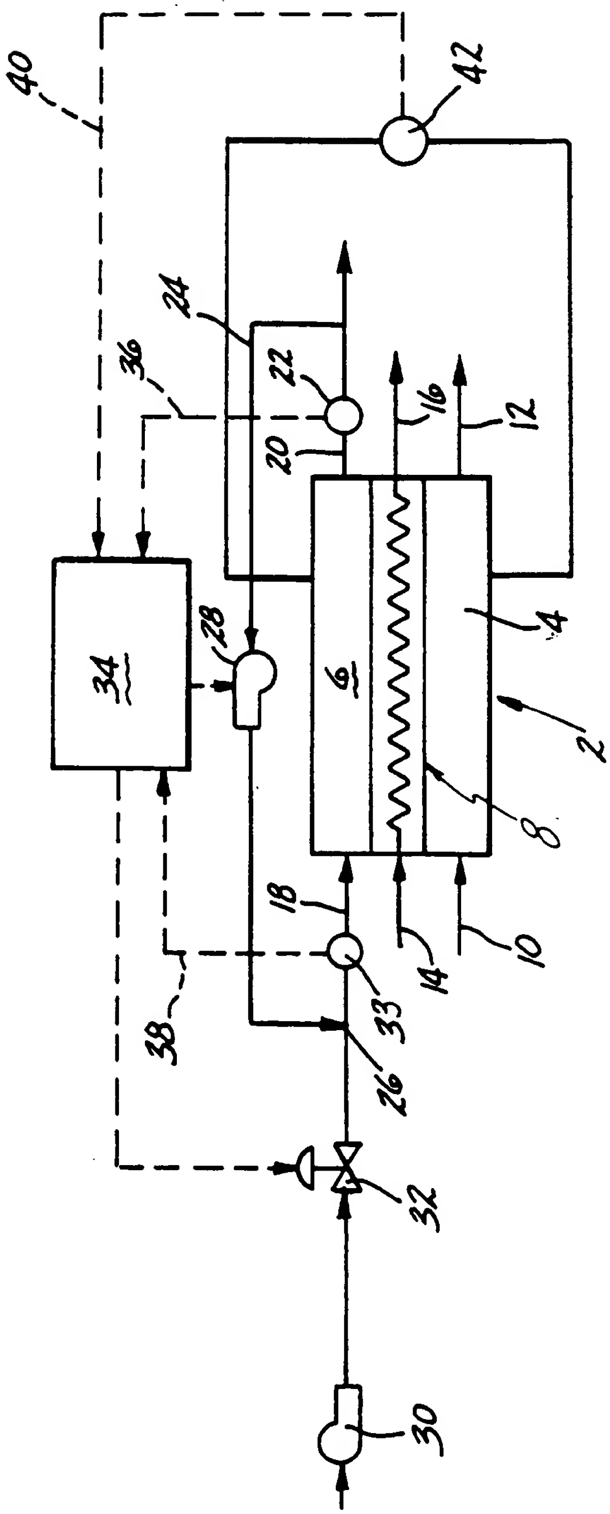
l'étape du calcul de l'oxygène consommé en mol/h comprend la multiplication du courant mesuré en ampères par $2{,}06 \times 10^{-5}$; et

l'utilisation d'oxygène (UO_2) est calculée selon:

$$UO_2 = \frac{O_2CONS}{O_2CONS + XO_2(Win + O_2CONS)}$$

où O_2CONS est l'oxygène consommé, XO_2 est la teneur fractionnelle en oxygène de l'air d'échappement, Win est l'écoulement mesuré entrant dans la cathode exprimé en unités consistantes.

7. Procédé selon la Revendication 4, ***caractérisé en ce que*** la quantité d'air recyclé est augmentée lorsque la puissance du courant en sortie diminue.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